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Power Beaming Technology Vision & Goals

NASA

Goal: ***Develop a High-Power (HP) directly solar pumped laser that is efficient at converting solar energy to laser energy, beaming this energy through the atmosphere, and converting it back to usable electrical energy on the earth or other aerospace platforms.***

Value Added: ***Removal of one conversion step (photovoltaic) in harvesting solar power.***

Technology Development:

- *Replace Heliostat array with microwave sulfur lamps for Laboratory experiments*
- *Create Single fiber laser Capable of HP output and direct solar pumping*
- *Integrate single fibers in a phase locked Fiber laser Array with a large aperture*

Capabilities:

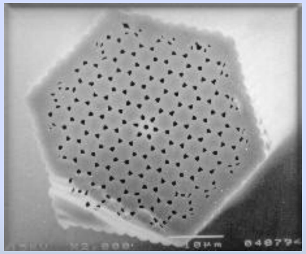
- *Testing of solar pumped fiber laser arrays in a lab*
- *Fiber Fabrication & Integration*
- *Large Scale Tests*

When Expected:

2004 — 2005 — 2006 — 2007 • • • > 2020

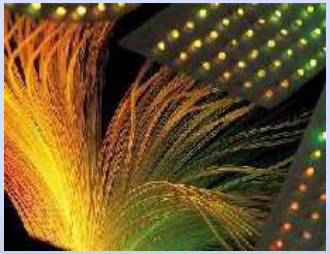
Present lab facilities Are not ideal for short experiments.

Simulating the sun in a laboratory

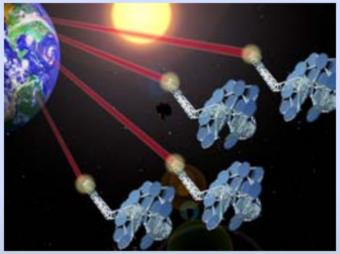


Development of HP Fiber Laser

Atmospheric modeling for long distance propagation of HP Pulses



Integration of fibers To make HP Array



Space Based SSP Array

Note: The images shown are only representative technologies from several organizations

Power Beaming Objectives & Program Status

- ***Objective :*** ***To develop a directly solar-pumped laser system that is capable of deep atmospheric propagation with low loss.***
- ***Innovation Desired:*** ***Use the atmosphere to an advantage instead of a its current disadvantaged by using atmospheric nonlinear properties for self-focusing & low loss transmission. It is desired to achieve this through large scale fiber laser development.***

- ***Program Status:***
  - ***Identified emerging and enabling physics.***
  - ***Designed primary mirror optics integrated into flexible satellite structure.***
  - ***Designed light trap to act as pre resonator chamber.***
  - ***Fabricating hardware mirror optics for satellite prototype.***
  - ***Initial fiber bundling experiments failed, so a redesigned fab-rication technique based on process is being used to build a prototype fused fiber bundles. Initial samples look promising.***

Power Beaming Accomplishments

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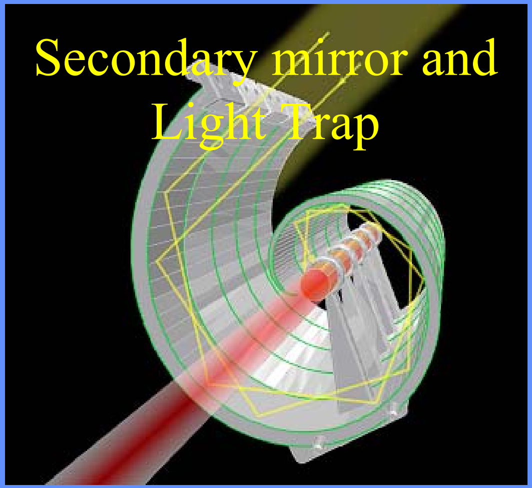
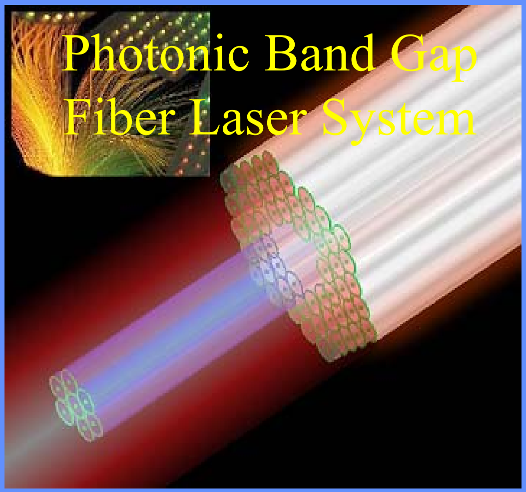
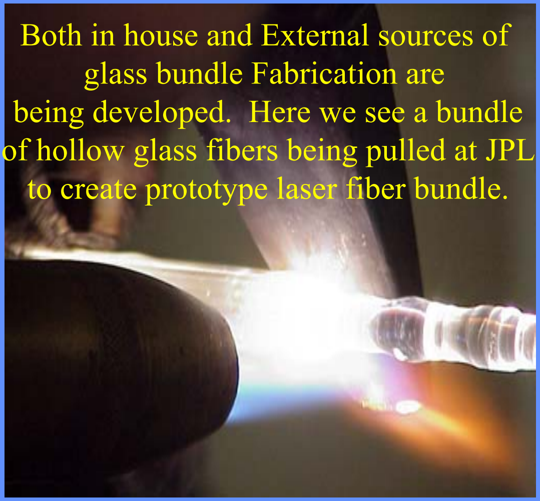






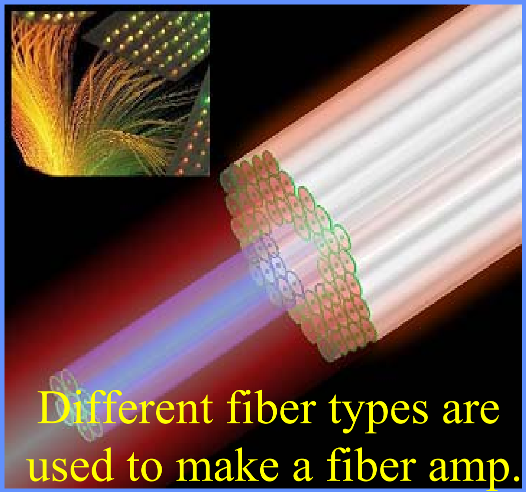
Fiber Laser Status
Third Quarter of 2002


Example
Fiber Fusing Holder

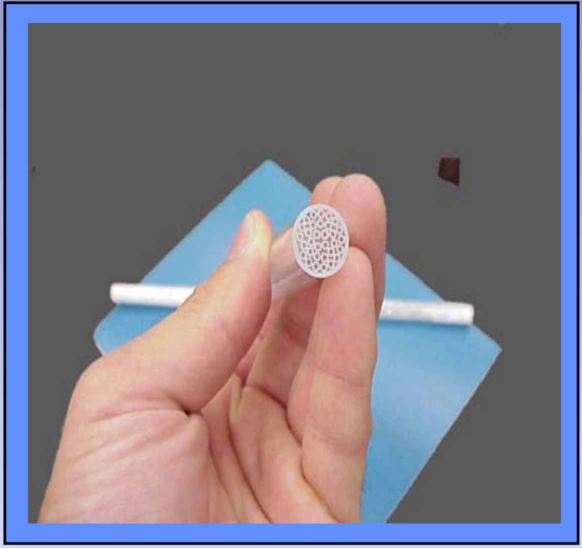
Initial efforts to develop a means to hold greater than 1 Million, fibers, in a well known and predefined configuration proved to be difficult. The approach was based on using high precision chemically etched metal gratings (left) to hold the fibers in place. Unfortunately, it is a very labor intensive process for constructing large apertures in excess of 1 meter diameter since fiber threading operations are very slow.

Today we are using a glass fusion process to form bundles with the required number of passive, active, and heat dissipation structures. In the next quarter we will attempt to fuse these structures together and integrate with the mirror hardware develop in the past quarter. The challenge is:

1) Fusing different viscosity glasses together
2) Choosing the correct “checker board” pattern to draw glass pre-forms into so as to achieve a photonic band gap material with selective mode filtering to assist fiber to fiber mode locking. This item will continue to FY03.


Different fiber types are used to make a fiber amp.

Fiber Laser Status
Third Quarter of 2002



We have fabricated different bundle geometries to explore the process of tube structures that will carry gas or liquid coolants and lasing medium. These structures will ultimately be placed In a light trap to be pumped to an excited Level for lasing.

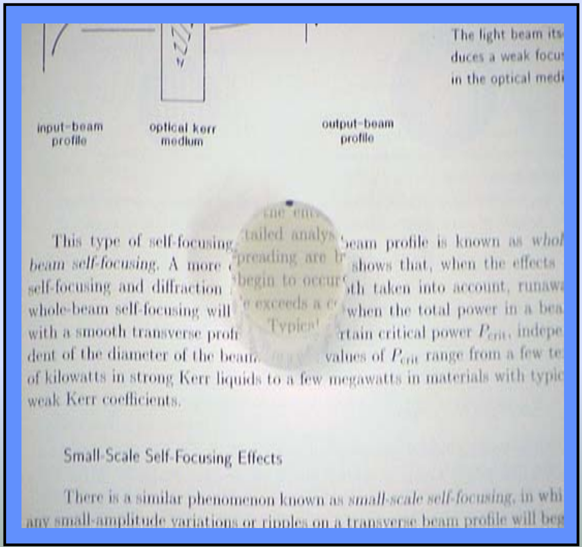
First a glass medium is chosen, then it is packed into larger glass holder tubes and the entire system is fused at temperatures in excess of 2500 C. These structures cur-rently are not optimized but we are moving towards having The thermal loads, flow rates, packing structures analyzed to give laser action when exposed to Large solar flux.

Fiber Laser Status
Third Quarter of 2002

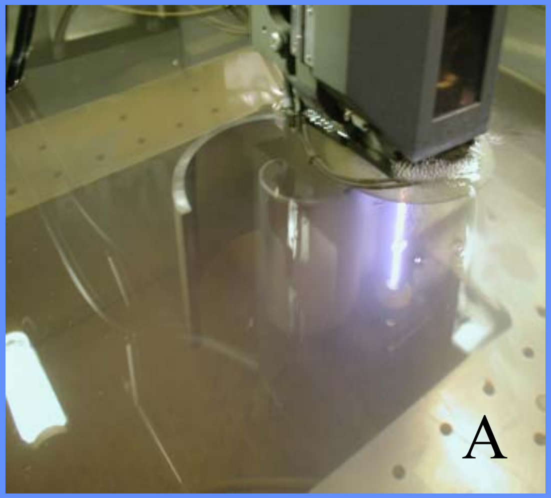
Thousands of fused fibers.

Additional efforts are underway to modify commercial fiber bundles so that they contain active fibers and heat dissipation structures, i.e. tubes, for heat transfer. This effort will extend into next FY. To the left we see such a bundle with thousands of fused fibers.

Although the SSP application requires only non imaging optics it is still possible to see how the fused fiber optic wave-guides (right) can carry optical information. The next step is large area amplification and fiber-to-fiber phase locking

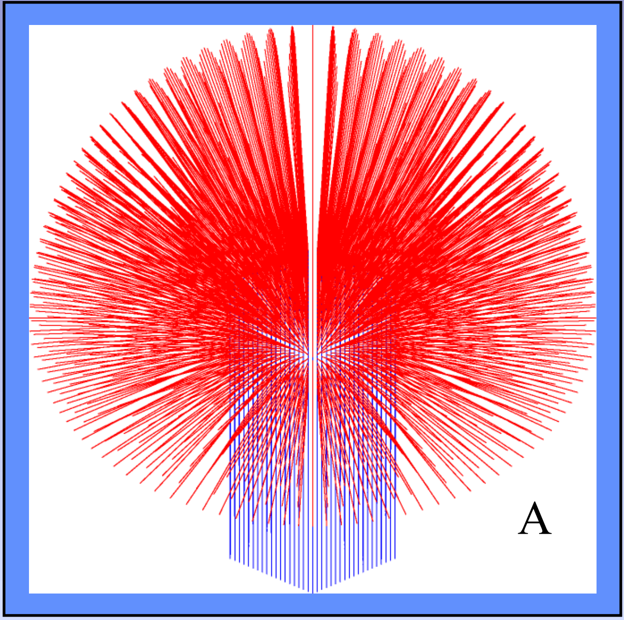


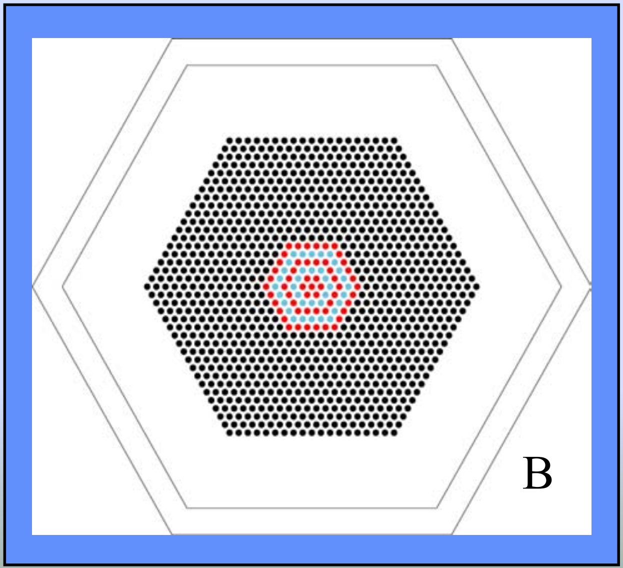
Fiber Laser Status
Third Quarter of 2002



A Snail Light Trap is currently being extruded (A) in a special metal forming process. In (B) we see part of a thin section of the metallic extrusion which forms a high precision mirror and fiber bundle holder. The light trap is what we call a "Preresonator Chamber" for solar energy pumping of fibers. The fiber bundle, shown inside, will eventually hold hundreds of thousands or even millions of Optical fibers in future designs. These fibers that are forced to work together by Nonlinear inter fiber interactions and phase lock to form a large area coherent field. At this time most of the effort has gone into picking mirror geometries. The next phase is to design the fiber bundle to optimize the optical fields.

Fiber Laser Status
Third Quarter of 2002



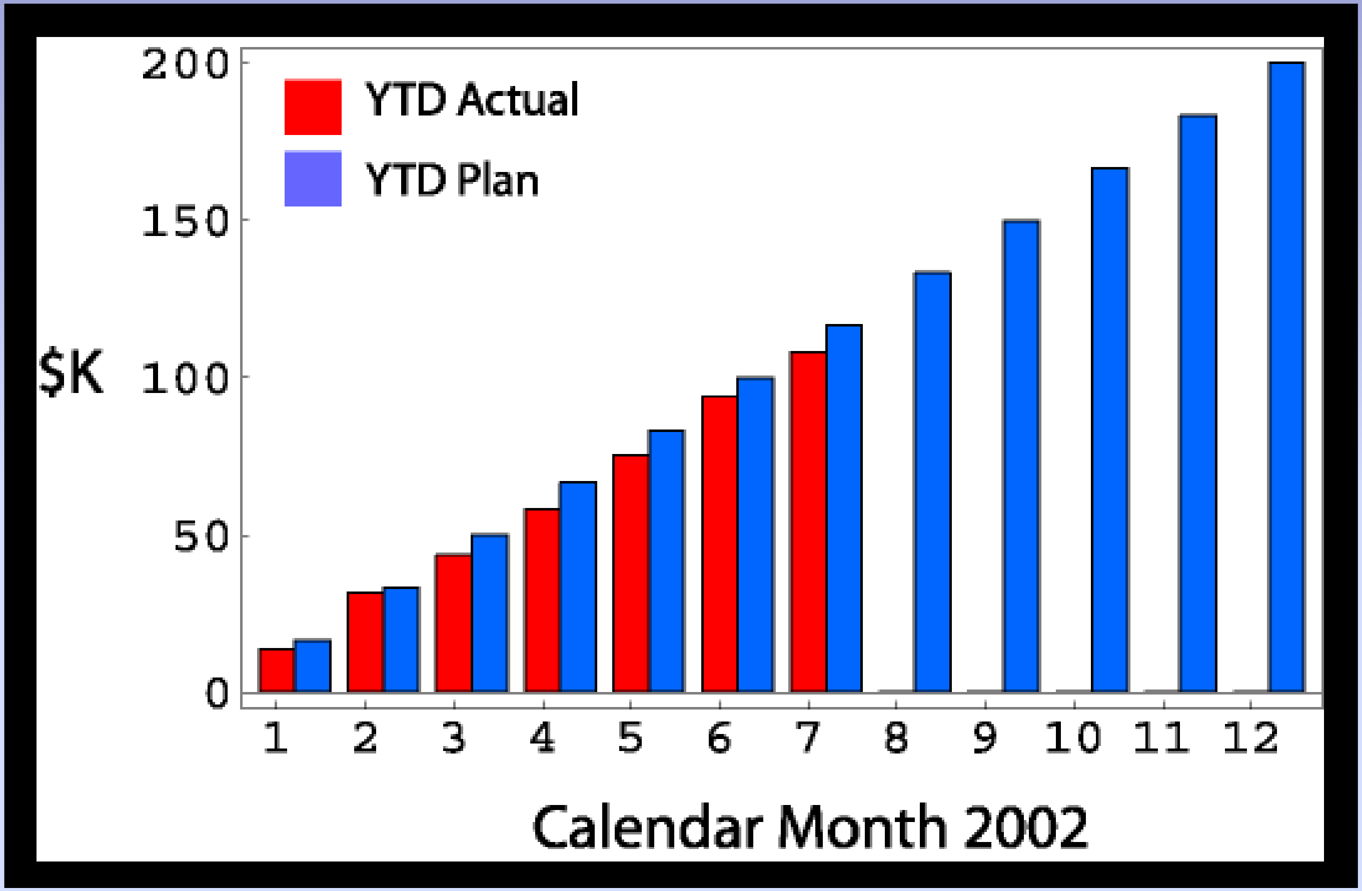


There are an infinite number of possible geometries for packing the fibers. However, these geometries are constrained by the need to efficiently pump them either directly or through a diffusion process. Fig. (A) shows one possible directly pumped laser fiber ball (red) that feeds a close packed fiber bundle (blue). Light is initially absorbed at the ball.

In addition to the three dimensional layout of the fibers there are also concerns on how to design the individual placement of the fibers in the two dimensional bundle. In Fig. (B). we see one example of placing different doping level fibers (red and blue) in different locations on the bundle axis. The physics of this placement problem will be investigated in detail during that upcoming quarter and next FY.

Budget Status

Cumulative Expenditures for 2002



Average monthly rate = $15.4 K

Expected hardware development will bring expenditures up to planned levels over the rest of the year.

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Power Beaming Customer Relevance

- ***Targeted Customer Base***
  - ***Space Science***
    - ***Photonic Band Gap Materials development for space applications***
    - ***Upper atmosphere broad spectrum white generation for stratosphere spectroscopy***
  - ***Human Exploration and Development of Space Enterprise***
    - ***Beamed power propulsion concept and development***
    - ***Space solar sail development and demonstration***
  - ***Commercial Applications***
    - ***Long duration autonomous vehicles for communications and remote sensing***
    - ***High power mining (both space and terrestrial)***
    - ***Line of site optical Telecommunications***
- ***Co-funding Arrangements***
  - ***Current Commitments***
    - ***Other NASA Center Participation in SSP***
    - ***University-conducted activities and partnership. Currently interacting with Caltech, Rutgers University, and the University of Michigan.***